

What is claimed is:

- 1 1. An in-line holographic mask for patterning a workpiece, formed by a process  
2 comprising the steps of:
  - 3 a) providing an illumination source for generating a coherent illumination  
4 beam directed along an axis;
  - 5 b) providing a non-opaque object mask having a semi-transparent layer with an  
6 optical density between 0.1 and 5.0, said object mask capable of  
7 transmitting a portion of said illumination beam as undiffracted reference  
8 wavefronts, and having one or more substantially transparent elements for  
9 creating overlapping object wavefronts when said illumination beam is  
10 incident thereon;
  - 11 c) disposing said object mask in said illumination beam;
  - 12 d) providing a holographic recording medium in said illumination beam  
13 adjacent said object mask;
  - 14 e) illuminating said object mask with said illumination beam, thereby causing  
15 said object mask to allow undiffracted reference wavefronts to pass  
16 therethrough, and causing said one or more elements to create object  
17 wavefronts which interact with said undiffracted reference wavefronts to  
18 create an interference pattern wherein said reference wavefronts and said  
19 object wavefronts have a beam ratio between 0.1:1 and 100:1; and  
20 f) recording said interference pattern in said holographic recording medium so  
21 as to create a substantially continuous diffracting region over said  
22 holographic recording medium.
- 1 2. An in-line holographic mask according to claim 1, wherein said one or more  
2 transparent elements are selected from the group of elements consisting of phase-altering,  
3 scattering, refracting, and diffracting.

1     3.     An in-line holographic mask according to claim 1, wherein said step e) involves  
2     scanning said illumination beam over said object mask during said recording of said  
3     interference pattern.

4     4.     An in-line holographic mask according to claim 1, wherein said semi-transparent  
5     layer is chrome.

1     5.     An in-line holographic mask according to claim 1, wherein said at least one or  
2     more transparent elements comprise an array of transparent elements.

1     6.     An in-line holographic mask capable of patterning a workpiece, formed by a  
2     process comprising the steps of:

- 3         a)     providing an illumination source for generating a coherent illumination  
4                beam directed along an axis;
- 5         b)     providing a substantially opaque object mask having one or more  
6                substantially transparent elements for creating object wavefronts when said  
7                illumination beam is incident thereon;
- 8         c)     disposing said object mask in said illumination beam;
- 9         d)     providing a holographic recording medium in said illumination beam  
10                adjacent said object mask;
- 11        e)     illuminating said object mask with said illumination beam, thereby causing  
12                said one or more elements to create object wavefronts;
- 13        f)     providing a reference beam that is coherent with said illumination beam and  
14                has reference wavefronts that are in-line with said object wavefronts and  
15                that interact with said object wavefronts so as to create an interference  
16                pattern and wherein said reference beam and said illumination beam have a  
17                beam ratio between 0.1:1 and 100:1; and

18           g)     recording said interference pattern in said recording medium so as to create  
19                   a substantially continuous diffracting region over said holographic recording  
20                   medium.

1     7.     An in-line holographic mask according to claim 6, wherein said one or more  
2     elements are selected from the group of elements consisting of phase-altering, scattering,  
3     refracting, and diffracting.

1     8.     An in-line holographic mask according to claim 6, wherein said step e) involves  
2     scanning said illumination beam over said object mask and wherein said step f) involves  
3     simultaneously scanning said reference beam over said holographic recording medium.

1     9.     An in-line holographic mask according to claim 6, wherein said reference beam  
2     provided in said step f) comprises a portion of said illumination beam.

1     10.    An in-line holographic mask according to claim 6, wherein said step f) involves  
2     combining said reference wavefronts and said object wavefronts with a beam combiner  
3     disposed between said mask and said recording medium so as to make said reference  
4     wavefronts and object wavefronts in-line.

1     11.    An in-line holographic mask for patterning a workpiece, formed by the process  
2     comprising the steps of:

- 3           a)     providing a substantially opaque object mask having a surface normal and  
4                   one or more substantially transparent elements for creating object  
5                   wavefronts when an illumination beam is incident thereon;  
6           b)     recording, in a first holographic recording medium disposed adjacent said  
7                   mask, a hologram capable of forming an in-focus real image at an in-focus  
8                   real image plane and a defocused real image at a defocused real image  
9                   plane;

- 10           c)     disposing a second holographic recording medium in said defocused real  
11 image plane;  
12           d)     illuminating said hologram so as to create said defocused real image;  
13           e)     providing a reference beam that interacts with said defocused real image so  
14 as to create an interference pattern; and  
15           f)     recording said interference pattern in said second holographic recording  
16 medium so as to create a substantially continuous diffracting region over  
17 said holographic recording medium.

1     12.     An in-line holographic mask according to claim 11, wherein said one or more  
2 elements are selected from the group of elements consisting of phase-altering, scattering,  
3 refracting, and diffracting.

1     13.     An in-line holographic mask according to claim 11, wherein said step b) involves  
2 recording said hologram by (i) illuminating said object mask with a first coherent  
3 illumination beam incident said object mask at an angle with respect to said object mask  
4 surface normal and (ii) simultaneously illuminating said first recording medium with a  
5 first reference beam that is coherent with said first illumination beam and normally  
6 incident said first recording medium.

1     14.     An in-line holographic mask according to claim 11, wherein said step b) involves  
2 recording said hologram by (i) illuminating said object mask with a first coherent  
3 illumination beam at normal incidence with respect to said object mask surface normal,  
4 and (ii) simultaneously illuminating said first recording medium with a first reference  
5 beam that is coherent with said first illumination beam, at normal incidence to said first  
6 recording medium.

1 15. An in-line holographic mask according to claim 11, wherein said step b) involves  
2 scanning an illumination beam over said object mask while a reference beam is  
3 simultaneously scanned over said first holographic recording medium.

1 16. An in-line holographic mask for patterning a workpiece, formed by the process  
2 comprising the steps of:

- 3 a) providing a substantially opaque object mask having one or more  
4 substantially transparent elements for creating overlapping object wavefronts  
5 when an illumination beam is incident thereon;
- 6 b) recording a hologram of said object mask as a first interference pattern in a  
7 first holographic recording medium disposed adjacent said object mask;
- 8 c) removing said object mask and further recording in said first recording  
9 medium a second interference pattern;
- 10 d) illuminating said hologram thereby creating (i) diffracted wavefronts arising  
11 from diffraction by said first interference pattern in said hologram, which  
12 form an in-focus real image at an in-focus image plane and (ii) second  
13 reference wavefronts arising from diffraction by said second interference  
14 pattern in said hologram which interacts with said diffracted wavefronts so  
15 as to create a third interference pattern; and
- 16 e) recording said third interference pattern in a second holographic recording  
17 medium disposed adjacent said hologram and in a defocused image plane  
18 displaced from said in-focus image plane of said hologram as a substantially  
continuous diffracting region over said holographic recording medium.

1 17. An in-line holographic mask according to claim 16, wherein said one or more  
2 elements are selected from the group of elements consisting of phase-altering, scattering,  
3 refracting, and diffracting.

1 18. An in-line holographic mask according to claim 16, wherein step b) involves using  
2 an illumination beam normally incident on said object mask, and an off-axis first reference  
3 beam, and step c) involves forming said second interference pattern using said first  
4 illumination beam and said off-axis reference beam.

1 19. An in-line holographic mask according to claim 16, wherein said step b) said  
2 illumination beam is scanned over said object mask while a reference beam is  
3 simultaneously scanned over said first holographic recording medium.

4 20. An in-line holographic mask as in one of claims 2, 7, 12 or 17, wherein said one  
5 or more phase-altering elements are indentations in said object mask.

1 21. An in-line holographic mask as in one of claims 2, 7, 12 or 17, wherein said one  
2 or more said phase-altering elements are islands of transparent material.

1 22. An in-line holographic mask as in one of claims 2, 7, 12 or 17, wherein said one  
2 or more scattering elements are diffusers.

3 23. An in-line mask as in one of claims 2, 7, 12 or 17, wherein said one or more  
4 scattering elements has a preferred directionality.

1 24. An in-line holographic mask as in one of claims 2, 7, 12 or 17, wherein said one  
2 or more refracting elements are lenslets.

1 25. An in-line holographic mask as in one of claims 2, 7, 12 or 17, wherein said one  
2 or more diffracting elements are gratings.

3 26. An in-line holographic mask as in one of claims 2, 7, 12 or 17 wherein said one or  
4 more diffracting elements are holograms.

1 27. A method of creating a pattern on a workpiece comprising the steps of:

- 2 a) providing a source of illumination for generating a reconstruction beam  
3 having a reconstruction beam wavelength and reconstruction fluence and  
4 extending along an axis;  
5 b) disposing on said axis an optically made in-line holographic mask that  
6 creates a holographic image corresponding to a pattern when illuminated  
7 with said reconstruction beam;  
8 c) disposing a workpiece on said axis adjacent said holographic mask; and  
9 d) illuminating said in-line holographic mask with said reconstruction beam so  
10 as to form said holographic image on said workpiece and impart said  
11 pattern to the workpiece.

1 28 A method of creating a pattern on a workpiece according to claim 27, wherein said  
2 in-line holographic mask is made using surface relief patterning of a material that is  
3 substantially transparent and resistant to damage at said reconstruction beam wavelength  
4 and fluence.

1 29. A method of creating a pattern on a workpiece according to claim 28, wherein said  
2 in-line holographic mask is as in claim 1, 2, 6, 7, 11, 12, 16 or 17.

1 30. A method of creating a pattern on a workpiece according to claim 29, wherein the  
2 workpiece is coated with a layer of material sensitive to said reconstruction beam  
3 wavelength.

1 31. A method of creating a pattern on a workpiece according to claim 30, wherein said  
2 layer of material is a polymer.

1 32. A method of creating a pattern on a workpiece according to claim 30, wherein said  
2 layer of material is photoresist.

1 33. A method of creating a pattern on a workpiece according to claim 29, wherein said  
2 illumination beam wavelength is different from said construction wavelength.

1 34. A method of creating a pattern on a workpiece according to claim 27, wherein said  
2 reconstruction beam wavelength is between IR to DUV.

1 35. A method of patterning a workpiece comprising the steps of:

- 2 a) providing a source of illumination for generating a reconstruction beam
- 3 extending along an axis;
- 4 b) disposing on said axis a workpiece having a surface S;
- 5 c) providing a lens having an object plane and an image plane disposed
- 6 between said source of illumination and said workpiece such that said
- 7 image plane is proximate said surface S of said workpiece;
- 8 d) disposing an in-line holographic mask, capable of forming a real image,
- 9 between said source of illumination and said lens;
- 10 e) illuminating said in-line holographic mask with said source of illumination
- 11 and forming said real image at or near said lens object plane; and
- 12 f) transmitting said real image with said lens to a location at or near said
- 13 surface S of said workpiece.

1 36. A method of patterning a workpiece according to claim 35, wherein said in-line  
2 holographic mask is that of claim 1, 2, 6, 7, 11, 12, 16 or 17.

1 37. A method of holographically patterning a workpiece comprising the steps of:



2           a) providing an in-line holographic mask in-line with the workpiece, said in-line  
3           holographic mask having a substantially continuous diffractive region capable of forming a  
4           real image consisting of one or more high-intensity regions; and

5           b) illuminating with a reconstruction beam having a reconstruction wavelength said  
6           substantially continuous diffractive region of said holographic mask, thereby forming one  
7           or more patterns on the workpiece corresponding to said one or more high-intensity  
8           regions of said real image.

1       38.    A method of holographically patterning a workpiece according to claim 37,  
2       wherein said reconstruction beam has a wavelength between IR to x-ray.

1       39.    A method of holographically patterning a workpiece according to claim 38,  
2       wherein said in-line holographic mask is made optically at a construction wavelength  
3       different from said reconstruction wavelength.

1       40.    An apparatus for patterning a workpiece comprising:

- 2           a)     a source of illumination, having an associated wavelength, for generating a  
3           reconstruction beam extending along an axis;  
4           b)     an in-line holographic mask disposed on said axis adjacent said source of  
5           illumination; and  
6           c)     a workpiece holder disposed on said axis adjacent said in-line holographic  
7           mask.

1       41.    An apparatus for patterning a workpiece according to claim 40, wherein said  
2       in-line holographic mask is made optically at a construction wavelength different from  
3       said source of illumination associated wavelength.

1 42. An apparatus for patterning a workpiece according to claim 41, wherein said in-  
2 line holographic mask is a transparent relief hologram formed in a substrate capable of  
3 transmitting electromagnetic energy having a wavelength in the range from IR to x-ray.

1 43. An apparatus for patterning a workpiece according to claim 40, wherein said in-  
2 line holographic mask is one as in claim 1, 2, 6, 7, 11, 12, 16 or 17.

1 44. An apparatus for patterning a workpiece according to claim 40, wherein said  
2 reconstruction beam has a wavelength between IR to x-ray.

1 45. An apparatus for patterning a workpiece, comprising:  
2 a) a source of illumination;  
3 b) a workpiece holder;  
4 c) a lens having an object plane and an image plane, said lens disposed  
5 between said source of illumination and said workpiece holder; and  
6 d) an in-line holographic mask capable of forming a real image, said mask  
7 being disposed between said source of illumination and said lens such that  
8 said real image is formed at or near said object plane of said lens.

1 46. An apparatus for patterning a workpiece according to claim 45, wherein said in-  
2 line holographic mask is one as in claim 1, 2, 6, 7, 11, 12, 16 or 17.

1 47. An apparatus according to claim 45, wherein said source of illumination is capable  
2 of generating a reconstruction beam extending along an axis and said workpiece holder  
3 and said mask are positioned on said axis.

1 48. A workpiece patterned using the method of patterning a workpiece as set forth in  
2 claim 27.

- 1 49. A workpiece patterned using the method of patterning a workpiece as set forth in
- 2 claim 37.